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ABSTRACT

The progress theorists have made toward developing models of second-language acquisition suggests that researchers need to pay more attention to classroom data. Computer-assisted language learning (CALL) can link theory to practice. A review of the connections between second language acquisition theory and CALL points out several factors, including: (1) second language pedagogy must be reconnected to theory and empirical research; (2) classroom-oriented research can make a valuable contribution to understanding second language acquisition processes; (3) the use of the computer as a basic tool in second language acquisition research can provide new and detailed kinds of data; (4) computers have the capabilities to recycle the results of empirical investigations into the classroom; (5) using the computer in the language classroom offers a convenient means of deriving issues and questions for research; and (6) a reconnection of pedagogy and theory may be further advanced from computer-assisted research into the psycholinguistic processes of language learning. (CB)

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Relating Second-Language Acquisition Theory to CALL Research and Application

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Introduction

How students can be brought to learn a second language efficiently is, perhaps, the most compelling question language teachers ask of themselves. Traditionally, there have been two investigatory approaches to an answer: classroom teachers have gained insight into language learning by observation and teaching; and simultaneously, researchers have attempted to formulate theoretical models to explain the complex process of second-language acquisition (SLA). For some time, however, the language teaching field has suffered from a distrust of what theory and research can offer pedagogy because the thinking of theorists is often "loaned" (though unsolicited) from disciplines such as linguistics and cognitive psychology, whose fundamental precepts do not have second-language learning as a primary concern. Bits of information that "seem" useful for the classroom have been passed along as wisdom to be "applied," but little effort has been made to evaluate the relationship between theoretical knowledge and classroom practice (Jarvis, 21); consequently, much of this "wisdom" has been inappropriate for teaching. Recently, however, there has been a renewed determination to remain

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focused on theory in order to understand better how students learn a foreign language and how to make teaching more efficient. The key to success in reaching such an understanding is twofold: first, there must be a commitment to develop a specific theory that explains SLA processes; second, there must be a concentrated effort to collect data relevant to *classroom* second-language learning. Instead of relying on knowledge "imported" from other disciplines, the underlying motivation for an understanding of the psycholinguistic processing of second-language learning must now come from within the field of applied linguistics itself (Jarvis, 21). Accordingly, the second-language classroom should be recognized as a vital research milieu and a source of important data for responsible hypothesis formation vis à vis the psycholinguistic processes reflected in what Long (33) calls students' instructed interlanguage development.

Many applied linguists are also classroom foreign or second-language teachers, a qualification that promotes a mutually beneficial relationship between research and pedagogy, and one that has engendered a new concentration on classroom-oriented research. As called for in the early 1980s (Stern and Cummins, 55), and in reaction to the 1970s focus on second-language acquisition in a natural setting, classroom language learning is considered to be an important source of knowledge about SLA, rather than merely to "mirror" untutored, or "naturalistic," language-learning environments (Seliger and Long, 48). As such, classroom research now "counts" as basic theoretical research. Two major benefits derive from this perception: First, as suggested by Pederson in Chapter 5 of this volume, teachers can contribute important insights into the formulation of hypotheses about second-language learning; and second, the potential to improve the quality of classroom teaching through informed materials design and/or the reorganization of classroom activities based on research results is large (Pica and Doughty, 42). Long (29) has suggested that, if these benefits are to be realized in practice, teachers should be trained as researchers in order to interpret reports of empirical findings knowledgeably in relation to their classrooms and in order to contribute their own efforts intelligently to the monumental task of data collection.

Yet even when classroom research and teacher input are seen as equally vital to understanding second-language acquisition, the difficulty of directly observing language acquisition remains a significant problem. To this end the computer has become an important ally in research efforts to collect data detailed enough to shed light on the complex processing and causal variables involved in SLA. Depending on the research aims, computers can be employed in conjunction with or in place of audio and video recorders or human observers and made to follow elaborate and carefully constructed formats for classroom observation. Some advantages of using the computer as a research tool include more control over the collection, examination, and manipulation of data, as well as convenience (and speed) of data recording, storage, and computation within an appropriate

experimental design. Since these capabilities promise to facilitate the collection and analysis of behaviors that reflect underlying SLA processes at work, it is clear that CALL research can make an important contribution to the basic research effort "to discover something about the way in which students best learn a language," (Pederson, p. 108 this volume). Moreover, the information discovered in research via the computer can be recycled quickly and easily into the learning environment, thereby improving the quality of everyday classroom instruction.

Since it is clear that neither pedagogy nor theory alone has been able to elucidate the myriad of factors involved in learning a second language, one purpose of this chapter is to discuss the progress theorists have made toward developing models of second-language acquisition. Another purpose is to suggest that researchers pay more attention to classroom data; still another is to underscore that computer-based research on CALL provides an efficient means to accomplish this liaison. To summarize, these important points will be addressed:

1. Second/foreign language pedagogy must be reconnected to theory and empirical research, but the specific motivation to do so must come from a concern for a detailed understanding of SLA shared by researchers and teachers.
2. Classroom-oriented research can make a valuable contribution to understanding SLA processes.
3. The use of the computer as a basic tool in SLA research can provide new and detailed kinds of data.
4. Computers have the capabilities to recycle the results of empirical investigations into the classroom almost at once. Thus, computers make classroom-oriented research methodology accessible to teachers who might not otherwise have time but wish to conduct classroom studies in order to tailor their own instruction to specific individuals or groups of students.
5. Conversely, using the computer in the language classroom offers a convenient means of deriving issues and questions for research that appear in the classroom learning environment.
6. Finally, there is some chance that a reconnection of pedagogy and theory can be further advanced through computer-assisted research into the psycholinguistic processes of language learning.

The extent to which psycholinguistic processing is insufficiently understood will become apparent in the course of examining several SLA models that attempt to describe how language data are integrated into the learner's changing interlanguage grammar (known as interlanguage development) and how such data are accessed and used by the learner under the pressure of communication.

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Theoretical Models of Second Language Acquisition

A comprehensive model of SLA with explanatory and predictive power has yet to be formulated. While some researchers have concluded that not enough is known to permit the construction of one comprehensive model (Stern, 54), others are more optimistic that the current status of theorizing, together with the body of empirical data amassed to date, indicate that a comprehensive theory is in the offing (Spolsky, 53). Most researchers agree that SLA is too complex a phenomenon to be explained at this stage by a single theory; rather, several models that account for various components of the overall process are thought to be needed to guide future research (Tollefson, et al., 56). To this end, if the purpose of a theoretical model is to facilitate the collection of information about SLA in general, necessary correlates are (1) defining specific research questions that evolve from the componential models themselves and (2) gathering empirical support for each. Ultimately, however, the cognitive processes involved in SLA must be viewed as a unified system (Andersen, 1). Once the empirical data has been collected and conclusions drawn from the research, the component models may be integrated to formulate one coherent theory.

Stern and Cummins (55) have provided a useful framework for the examination of models of second-language learning, as summarized in Figure 1. Within this framework, social context (dominance patterns, integration strategies, and group attitudes), learner characteristics (affective, personality, and cognitive characteristics, as well as age), and learning conditions (objectives, content, treatment, and evaluation) are the variables that affect the second-language learning process (strategies and processes) and its outcomes (interlanguage). Such a componential framework emphasizes an important point: the learning process is central to an understanding of SLA, which must ultimately be seen as an interaction between it as a central process and the variables that affect it, an interaction that then results in learning outcomes. Primarily because learning outcomes are more observable than processes, previous research has been devoted to investigating the effects of numerous variables and conditions on the outcomes of the learning process, thus bypassing the process itself. But, teachers and researchers now recognize the need to examine the learning process as directly as possible. Clearly, the computer is an invaluable tool for observing the variables that affect this process and, by extension, for building a comprehensive SLA theory.

Most research into the educational uses of computers has concentrated on examining the effectiveness of the medium in bringing about more efficient learning, particularly in comparison with traditional classroom instruction, and CALL research has often followed this same line of investigation—the investigation of the learning conditions in the Stern and Cummins (55) perspective. In such research, CALL is seen as a *treat-*

Factors	Attributes
Social Context	dominance patterns integration strategies group attitudes
Learner Characteristics	affective characteristics personality cognitive attributes age
Learning Conditions	objectives context treatment evaluation
SLA Learning Process	strategies processes
Outcomes	interlanguage

Figure 1. Factors That Influence the Learning Process and Their Attributes (adapted from Stern and Cummins, 55).

ment applied to the learner, and the effect of that treatment on learning is then measured. This product-oriented approach to the evaluation of the effectiveness of CALL has proven unsatisfactory primarily due to inattention to the central role of the learning process and the corresponding influence of learner characteristics. Recently, however, a very small amount of basic research implemented on computers has begun to address the learning process issue. Subsequent sections of this chapter relate research on CALL to issues in SLA theory and to the practicalities of connecting classroom teaching and research in general.

Concerns for Theory Construction

In any field, theories are formulated by (1) asking important questions, (2) developing models, (3) generating hypotheses therefrom, (4) testing the hypotheses, and (5) revising the models in accordance with the evidence gathered. This five-step process, which may be repeated any number of times taking into account new knowledge gained, defines the relationship between research and theory (Long, 29).

What, then, are the important questions of primary concern to theorists, researchers, and foreign language teachers? Spolsky (53) has put forth the fundamental question researchers must address in order to formulate a comprehensive SLA theory: "Who learns how much of what language under what conditions?" (p. 269). For the classroom language teacher, the language itself and the conditions under which it is studied are

perhaps better understood than are the learners or the learning process. Accordingly, the following discussion of SLA models and related CALL research addresses only the "who learns" issues. The five models summarized below outline the many differential effects of learner variables (i.e., individual differences) on the overall SLA process—the *who* component (Bialystok, 2)—but focus primarily on the *process* of SLA—the *learns* part of the question. Taken together, the five theoretical models represent a concise statement of contemporary thinking about many important aspects of SLA theory. Finally, the CALL research reviewed in association with these models reflects some initial computer-based efforts to incorporate classroom data into theoretical considerations of second-language acquisition.

The five models fall within three theoretical frameworks: Monitor Theory, Information-Processing Theory, and Interaction Theory. While Monitor Theory tries to be a comprehensive theory of SLA (but falls short), revisions of it together with constructs from Information-Processing Theory and Interaction Theory may be used to organize efforts in data collection. Once validated empirically, a combination of these theoretical models may explain several important elements of the overall process of SLA and bring applied linguistics closer to a unified theory of second-language acquisition. Some details of the models presented have been omitted so that their relative components may be compared and contrasted. The following template will be used for comparison purposes in conjunction with a graphic interpretation of each model (described at length elsewhere by their proponents).

In general, Monitor Theory à la Krashen attempts to be comprehensive, addressing all five parameters of the template, while Bialystok's revision of Monitor Theory (the Explicit/Implicit Knowledge Representation Model) offers alternative interpretations of the processing, storage, and access-use phases (defined below). The Information-Processing and interactional models seek to explain respectively the access/use and processing phases at a greater level of detail than does Monitor Theory.

Input refers to the language data to which the learner is exposed (i.e., that heard or read).

Processing represents the means by which input available to the learner becomes internalized as part of a developing interlanguage; this psycholinguistic processing has also been referred to as *intake* (Corder, 7),

reflecting the distinction between language that is simply available to the learner and that which actually contributes to the growth of the interlanguage grammar.

Storage reflects the memory format, or, in Bialystok's (2) terms, the knowledge representation (i.e., mental organization) of the interlanguage grammar.

Access is another psycholinguistic process, but one by which acquired knowledge may be retrieved from memory and used by the learner.

Output is composed of observable learner behaviors such as comprehension and production. The following discussion of the major components of Monitor Theory, Information-Processing Theory, and Interaction Theory will be delineated by the above template and will address the learning process and learner characteristics components of an overall model of second-language acquisition.

Monitor Theory

Krashen's Version

Monitor Theory (Krashen, 23) is well known to the majority of second-language professionals; its seminal concepts* have been vital stimuli to research. Although the theory as Krashen has proposed it has often been criticized as vague and untestable (Gregg, 18; McLaughlin 37; Pienemann, 44), several of its fundamental notions are valuable and continue to influence the thinking of SLA theoreticians (Long, 30). Figure 2 depicts a simple model of Krashen's Monitor Theory.

Monitor Theory consists of five hypotheses about second-language acquisition: the learning/acquisition hypothesis, the natural order hypothesis, the monitor hypothesis, the input hypothesis, and the affective filter hypothesis. These elements, familiar to readers, have been incorporated into Figure 2. The *learning/acquisition* distinction is made apparent by the separate representation of the two ways in which, according to Monitor Theory, language data may be internalized. Krashen defines "language acquisition" as "a subconscious process; language acquirers are not usually aware of the fact that they are acquiring language, but are only aware of the fact that they are using the language for communication," and Krashen says that "the result of language acquisition, acquired competence, is also subconscious. . . ." "Learning," on the other hand, refers to "conscious knowledge of a second language, knowing

*For the complete description of the Monitor Theory, see Stephen D. Krashen, *Second Language Acquisition and Second Language Learning*, Oxford, England: Pergamon Press, 1981 and Stephen D. Krashen, *Principles and Practices in Second Language Acquisition*, Oxford, England: Pergamon Press, 1982.

the rules, being aware of them, and being able to talk about them" (24, p. 10). Moreover, the way in which the input will be internalized is determined by the type of language exposure: only informal language exposure can lead to acquired knowledge, whereas formal exposure results only in learned knowledge (where "knowledge" here and in subsequent comparisons of models refers to information in the learner's developing interlanguage).

Krashen's other hypotheses clearly depend upon the learning/acquisition distinction. Perhaps the most controversial of all is the *monitor hypothesis* from which the theory takes its name and through which Krashen asserts that only acquired knowledge can be utilized to initiate L2 output. The function of learned knowledge, on the other hand, is as a form of editor (the monitor), which evaluates and corrects production from the acquired system. The *natural order hypothesis* states that the acquisition of grammatical structures occurs in a specific, predictable order. As such, this hypothesis relates only to acquisition, and Krashen has claimed that language behaviors mediated by learned knowledge (via the monitor) do not conform to this natural order. The crux of Monitor Theory, however, resides in the *input hypothesis,* which addresses the issue of how language is acquired. Krashen's (24) input hypothesis states that "a necessary . . . condition to move from stage i to stage $i + 1$ is that the acquirer understand input that contains $i + 1$ level input, where 'understand' means that the acquirer is focused on the meaning and not the form of the message [and where '$i + 1$' refers to a linguistic structure that is just beyond the current psycholinguistic processing level *(i)* of the acquirer]" (p. 21). Finally, the *affective filter hypothesis,* originally contributed to Monitor Theory by Dulay and Burt (12), states that affective variables, such as attitude, motivation, or personality factors, act either to facilitate or inhibit the psycholinguistic processing through which language data enters into storage in memory.

Several computer-based research studies conducted within a Monitor Theory perspective have attempted to explicate the process by which input is said to become comprehensible to the learner. Krashen (24) has specifically claimed that linguistic structures ("grammar") are acquired while attending to the meaning of an utterance in the input rather than by paying attention to its structure. In a study that postulated practice as important to the internalization of input and sought to determine the relative effectiveness of structured vs. meaningful practice on second-language acquisition (Schaefer, 47), learners were subjected to two sets of computer-based drills reflecting these two kinds of practice. Results indicated that semantic practice (vocabulary) is more effective than structural practice (grammar) in terms of success on semantic measures and that both kinds of practice are equally useful for structural measures (grammar tests). Thus, Schaefer concluded that meaningful practice leads to the acquisition of grammatical structures and further that meaningful con-

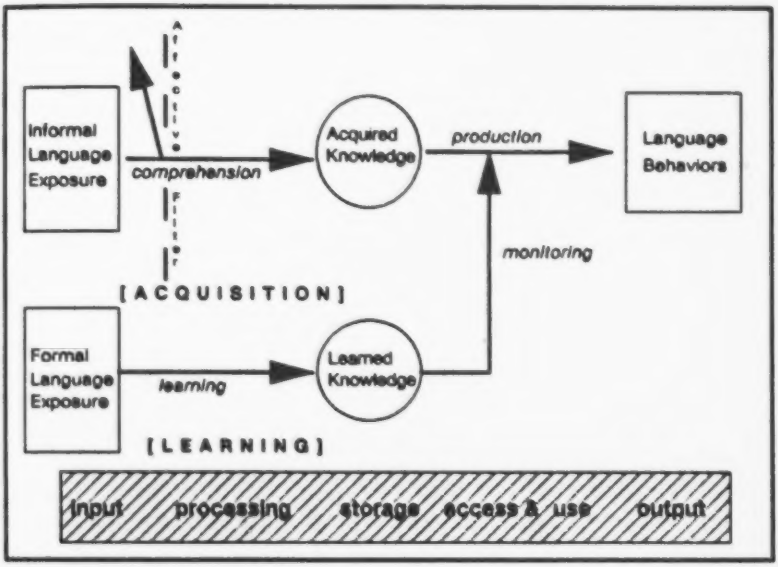

Figure 2. The Monitor Model

tent processing results in better understanding; moreover, since this practice was implemented on computers, Schaefer also concluded that meaningful processing of content is "not dependent upon interaction between people" but "can also take place by interacting with a medium such as a computer" (p. 137).

A study by Robinson et al. (46) at the Center for Language and Crosscultural Skills (CLCCS) in San Francisco investigated the effects of different strategies and different forms of error feedback on achievement. The study also investigated the relationships of various intelligence, motivation, and attitudinal factors (i.e., *learner characteristics*) with the effectiveness of CALL instruction. The questions asked by the researchers on Robinson's team were formulated by taking into consideration the importance of meaning in contrast to form. In their attempt to answer the perplexing question, What is the meaning of 'meaningful'? Robinson et al. utilized the computer primarily to present instruction in a controlled way. Accordingly, one hypothesis of the study was that "Practice in which the student is focused on the meaning of the material will lead to greater learning of structural items than will practice in manipulating the structures themselves, without reference to meaning" (p. 17). This ambitious study probed the above and other important issues and employed the computer to establish control over the presentation of the input. While some of the

results were inconclusive (as for example can be seen in the analyses designed to reveal the daily versus cumulative effects of CALL instruction), the CLCCS research effort is noteworthy from two standpoints (Doughty, 8): (1) hypotheses were carefully generated from a base of theoretical considerations, and (2) the study illustrates the convenience of the computer as a tool for such research.

In addition to probing the meaning of "meaning," CALL research has begun to investigate ways to determine a learner's *i* and *i* + 1 input-processing levels. Parsing algorithms (abstract methods of dissecting and interpreting input to a computer) have been utilized to develop computer programs that analyze the learner's interlanguage. One such research strategy, developed by Markosian and Ager (34), uses a context-free grammar implemented via a computer program to analyze learner responses to computer questions and generates drills according to specifications in accordance with the learner's current vocabulary level. This application conforms to Krashen's input hypothesis in that the program performs some low-level, computer-aided diagnoses to reveal the learner's current level of processing ability (at least in terms of vocabulary items) and generates drills that approximate that level. A logical next step might be to incorporate vocabulary that is just beyond (*i* + 1) the learner's current level of understanding (*i*), and to include that vocabulary in computer-mediated activities that provide opportunities to internalize the *i* + 1 input. Such research may make apparent the process through which *i* + 1 input becomes comprehensible. A similar and parallel direction for future research would be to apply the same experimental design to investigate the acquisition of target language syntax, particularly since Krashen's hypothesis intends to account for the acquisition of "grammar" rather than vocabulary.

Krashen has suggested that context provides the key information necessary to allow *i* + 1 input to be comprehended and incorporated into the developing interlanguage system. Recently, and to this end, Johns (22) has described a fascinating classroom application for an existing computational capability, the concordancing program. Concordancing programs search through a document for all the contexts around a specified word and present them in list form with the key words or phrases in their contexts vertically aligned in the center column on the screen. Via a concordancing program called Micro-concord, for example, the computer can offer "both language learners and language teachers a research tool for investigating 'the company that words keep'" (p. 151). Johns reports that the use of concordancing output has already been implemented in the teaching of advanced courses in English, Russian, and German, enabling "advanced learners to take the initiative in carrying out their own research into the variable rules of the language" (p. 151). An obvious connection to this pedagogical application of Micro-concord is the coupling of the

concordancing program with the computer's capability for storing records of the students' actions, known as the "learner log." In addition to documenting how learners use the program, the learner log maintains an ongoing evaluation and record of each student's current level of target language ability. Thus, teachers can easily collect valuable and detailed information about student efforts to utilize context as an aid to comprehension, in combination with documentation of the effects of these efforts on interlanguage development.

Three ideas contained in Monitor Theory have generated a great deal of discussion and research: the learning/acquisition distinction, the comprehension of $i + 1$ input as a causative factor in acquisition, and the assertion that acquisition takes place during comprehension rather than production. The first consideration may be referred to as the *knowledge representation problem* while the remaining ideas contribute to considerations about what may be termed the *acquisition problem*. Several revisions and alternatives to the Monitor Model attempt to grapple with both of them, as described below.

Bialystok's Revision of Monitor Theory

In addressing the acquisition problem, Monitor Theory holds that learning and acquisition are two different and entirely separate means of internalizing language, and further indicates that these processes lead to separate sets of language knowledge that, in turn, have different functions as well (i.e., production vs. monitoring). Monitor Theory also states that conditions affecting this input and its internalization determine the route by which the data are processed. Formal, structured conditions, such as those typically found in classrooms, trigger "learning," while a focus on meaning rather than on structure leads to acquisition. Moreover, since these two internalization paths are hypothesized to be separate, to have separate functions, and to lead to different storage formats in memory, Krashen has further asserted that learning cannot lead to acquisition. Alternatively, Bialystok (4) has proposed that these input internalization processes lead to distinct, *but related*, forms of language stored within the developing interlanguage. As evidence of this interrelatedness, Bialystok cites a capacity for the transfer of knowledge from one type of memory storage to another. Figure 3 provides one possible graphic description of Bialystok's Explicit/Implicit Knowledge Representation Model. The suggestion that language knowledge is stored in different forms evolved from the frequent observation that a learner may sometimes "appear to know" (i.e., "use") a particular construction of the target language and other times will seem to have forgotten it. For example, students often demonstrate skill in pattern practice drills, but cannot apply these paradigms in

everyday conversation. From this observation, Bialystok draws a conclusion slightly different from Krashen's: while agreeing that there are two entirely separate kinds of language knowledge resulting from two different internalization processes, Bialystok suggests that the two storage formats are not entirely independent of one another.

Because input is not permanently assigned to either explicit and implicit storage in the Bialystok model, this revision of Monitor Theory may be interpreted to state that learning *can* lead to acquisition and vice versa. In other words, while, like Krashen, Bialystok suggests that language knowledge may be stored differently in memory, the Explicit/Implicit Knowledge Representation Model departs from the Monitor Model in providing the insight that the setting (i.e., classroom vs. "natural"), which is the "trigger" for these specific internalization processes, does not necessarily determine the permanent location of the internalized input within memory storage. Moreover, other kinds of processing (such as access and use) may also influence the memory storage format by effecting its reclassification as either implicitly or explicitly organized knowledge.

A more detailed comparison of these two models, both of which find their grounding in Monitor Theory, reveals that Bialystok's revision accepts some elements of Krashen's learning/acquisition distinction but rejects others. As is the case with the Monitor Model, the Explicit/Implicit Knowledge Representation Model accepts that the content of each storage format in memory is determined by the process through which the data were internalized. An example that illustrates this distinction can be found in a comparison between foreign language classrooms, where a great deal of time is spent talking about the language as an object of study ("formal practicing" in Figure 3), and immersion classrooms, where the object of study is a particular content area and the medium of study is the target language ("functional practicing" in Figure 3). In the foreign language classroom, metalinguistic discussions are often accompanied by formal practicing; however, Bialystok cites *functional* practicing as the trigger for internalization along an acquisitional path. (Functional practicing is not clearly defined by Bialystok, but appears to be simply the *use* of the target language during the course of learning content material in immersion settings.) In contrast to Krashen, however, Bialystok postulates that although there are two different forms of storage for internalized language, there is a possibility for transfer of information between the two knowledge stores, which may be activated by any number of constraints on production (situational, interpersonal, task-related, etc.). These constraints on production initiate different psycholinguistic mechanisms for access and use processing which, in turn, affect the organization of the knowledge representation differently.

The two kinds of knowledge representation in Bialystok's model, explicit (or "conscious") and implicit (or "intuitive"), comprise a dichot-

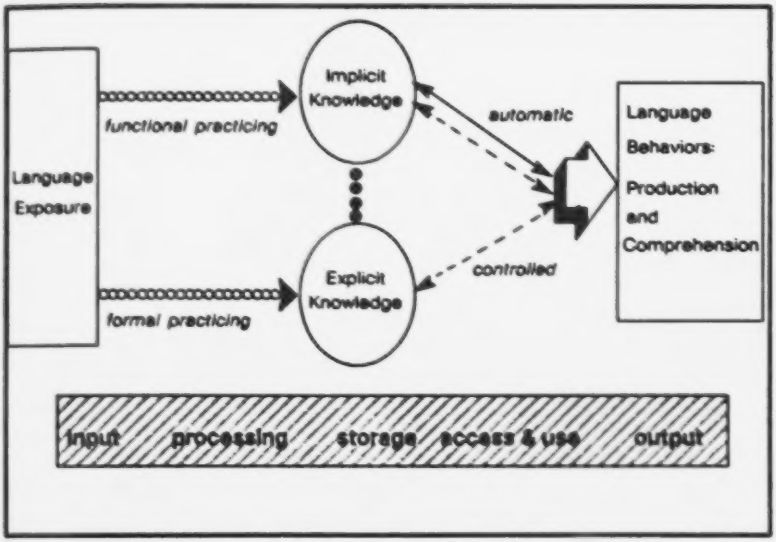

Figure 3. The Explicit/Implicit Knowledge Representation model

omy from other cognitive models of information of knowledge representation that differentiate analytic and intuitive knowledge. This distinction in cognitive psychology is the *know that* vs. *know how* opposition, which translates in language-learning theory to *know about language* vs. *be able to use language in communication*. As described in detail above, the language stores in memory can be reorganized by the process through which they are accessed, even after having been originally determined by the conditions surrounding the intake process. Bialystok (3) conducted a study designed to document both types of knowledge representation by setting up conditions that facilitated access to each. Results of the non-computer-based investigation revealed that subjects who attested to intuitive judgments of grammaticality could be further induced to provide indications of the kinds of errors they spotted and even to give some form of the rules that governed their decisions about the grammaticality of given constructs or sentences. Such analytical ability indeed points to some kind of interaction between the two forms of knowledge, but more evidence is needed to clarify the nature of the relationship.

A project underway at The Ohio University incorporates the notion of two kinds of processing for the internalization of input, resulting in implicit and explicit storage. The Computer Assisted Simulation of Language Use (CASLU) is a program whose design integrates activities in which students use language as a means to solve problems with a pedagogical component that tracks learner decisions and gives advice to aid

problem solving and to influence both the form and appropriateness of the target language that students produce (Soemarmo et al., 52). Thus, CASLU's evaluation of the students' performance is both implicit (because advice is given about choices made in solving the problem) and explicit (because language-specific knowledge is assessed and students are directed to exercises for practice in areas of difficulty).

One member of the CASLU team conducted a small computer-based study that demonstrated that vocabulary can be acquired while the learner focuses on the completion of a CALL problem-solving task rather than on memorizing the vocabulary items themselves (Magoto, 35). Learners were pretested on vocabulary items that were then incorporated into a CASLU problem-solving lesson. After completing the lesson, the students were given a posttest of the same vocabulary. Posttest scores were significantly higher than the pretest scores, suggesting that learning of the vocabulary items had occurred during the course of completing the problem-solving exercises. The posttest score, however, was determined immediately after the treatment, with no follow-up test after a period of time had passed. Another posttest, administered two weeks or one month later, for example, would have strengthened the interpretation of results. Replications of this research are needed along with modifications to the experimental design to determine long-term retention as well as to investigate whether syntax can be acquired during this kind of functional practicing that leads to implicitly organized knowledge.

In addition to departing somewhat from Krashen's notion of how language knowledge is represented in memory, Bialystok has also addressed the *acquisition problem* from a different perspective as well. In order to explain the effects of the various factors that influence learner's production described above (see p. 6), Bialystok has hypothesized that during L2 production, the process of accessing language in storage determines the transfer of information from one storage format to another. This perception details the important distinction between the Bialystok and Krashen versions of Monitor Theory alluded to above. In Bialystok's revised model, production is an important element in the overall acquisition process, whereas in Krashen's version acquisition is restricted to the comprehension process. Generally speaking, for Krashen, the explicit knowledge store is accessed in a controlled manner (with some degree of deliberateness or at some level of consciousness), and implicit knowledge may be reached automatically (or fluently). Currently, it is clear from Bialystok's (4) research that implicit knowledge may also be accessed deliberately and consciously because, when pressed, subjects who originally respond by intuition can identify errors as well as give explanations for them. Nevertheless, it is not yet clear how explicitly learned knowledge can be accessed automatically, and this explanation is crucial support for the claim that learning can lead to acquisition.

The importance of keeping a learner log that records all student actions

on a computer and stores all learner responses to CALL programs cannot be overemphasized in the effort to understand how students can be brought to access implicit knowledge automatically. In the CLCCS study by Robinson et al. (46), learner processing strategies were hypothesized to be responsive to error feedback from the computer program. Student responses and program feedback to input errors, together with student responses to error feedback, were stored for analysis and for comparison with achievement scores after the period of instruction had been completed. Further studies that seek to uncover the relationship between error feedback and strategies of learner access/use of language are clearly needed to identify the specific computer-based activities that encourage the kinds of accessing and use strategies that lead to the reorganization of the linguistic material within the learner's memory. Through these strategies, explicitly learned knowledge may become implicit, thus promoting the transition of knowledge from learning to acquisition.

Criticisms of Monitor Theory

While the notions incorporated within Monitor Theory are intuitively appealing and seem consistent with observed evidence, the theory, as stated, has been widely criticized. First, McLaughlin (37) has discounted much of the evidence Krashen has cited in support of the input hypothesis. Secondly, Gregg (18) and Pienemann (44) have pointed independently to an important difficulty with the learning/acquisition (conscious/unconscious) distinction: maintaining a distinction between learning and acquisition rests on providing evidence that the internalization of input may be either conscious or subconscious. While Krashen (23) has provided conceptual definitions of these processes (*learning* conscious grammatical judgments based on rules; *acquisition* subconscious grammatical judgments based on "feel"), both McLaughlin (37) and later Gregg (18) have suggested that it is impossible to distinguish these processes operationally. Operational definitions, the behaviors that reflect hypothesized processes, are standard to research, but following Krashen's definitions, whether subjects who said that they responded by "feel" did so in fact or gave that response because they did not know how to verbalize the rule cannot be determined. Bialystok's methodology is also lacking, to a certain extent, in operational definitions. And, although Bialystok has attempted to link learning and acquisition, there is a conceptual problem with envisioning any division (even with the proposed link) as well as with postulating how the link between the two knowledge stores would operate in memory.

A third reservation about Monitor Theory involves the inadequate explanation of $i + 1$ comprehensibility. Although the input hypothesis

claims that acquisition occurs when input slightly beyond the current processing capacity of the learner becomes comprehensible, neither Krashen nor Bialystok describe any specifically defined mechanisms by which input may be comprehended. Rather, Krashen states that learners must "notice the gap" (between their productions and the input around them) and be focused on meaning rather than on form in order to reconcile the differences between their interlanguage and the target language system. "Noticing the gap" is simply too vague a proposal to be tested empirically. Bialystok, on the other hand, postulates distinct practicing strategies to describe the internalization process, but similarly does not explain them.

There appears to be no organized and ongoing effort (directed by Krashen) to gather empirical evidence in support of Monitor Theory. Rather, there are many "restatements of known phenomena in the terminology of the [Monitor] model." (McLaughlin, 37, p. 320). But this is not unexpected in view of the untestable nature of the hypotheses that comprise it. From a pedagogical standpoint as well, Monitor Theory does not offer much hope of enhancing the effectiveness of instruction. If learning cannot lead to acquisition, then the only possible route to success in the classroom is providing comprehensible input, as Krashen has stated. Krashen and Terrell's (25) Natural Approach suggests that the classroom teacher must provide a nonthreatening environment in which input is made comprehensible to each individual learner. However, a specific methodology that creates these learning conditions is in its infancy and is not likely to be developed (or tested) until the operational definitions of the elements of Monitor Theory are described in detail.

Generally, then, Monitor Theory has been criticized on the basis of insufficient evidence in support of its very general hypotheses, which is not to say that Krashen's ideas addressing the acquisition problem and the knowledge representation problem are not worthy of further consideration (Long, 32). SLA models developed within Monitor Theory do not adequately explain the processes by which input enters the developing interlanguage system: thus, there is still a need to address the acquisition problem. Furthermore, although Bialystok has attempted to revise Monitor Theory with respect to the knowledge representation problem, there is no agreement within Monitor Theory about the form that language storage takes in memory. Alternative models have been proposed to resolve some of these difficulties. Information-Processing Theory and Interactional Theory, described below, are theoretical approaches that also address the difficult questions of how language knowledge is internalized and stored and, in combination with some elements of Monitor Theory, may help to provide an overall picture of second-language acquisition. Constructs from these theoretical frame-

works should also be incorporated into the design of future CALL research.

Information-Processing Theory

In contrast to Monitor Theory, Information-Processing Theory postulates another format for knowledge representation and the corresponding differences in the psycholinguistic processing of input that determines it (Nation and McLaughlin, 40). McLaughlin (37) emphasizes the significance of the influence of data retrieval on the storage format in memory, as does Bialystok, but succeeds in explaining further its significance. In other words, the ways in which they are accessed and used by the learner, are central concerns of information-processing theory. As can be seen in Figure 4, McLaughlin resolves some of the difficult questions inherent in Bialystok's conceptualization of the knowledge representation problem.

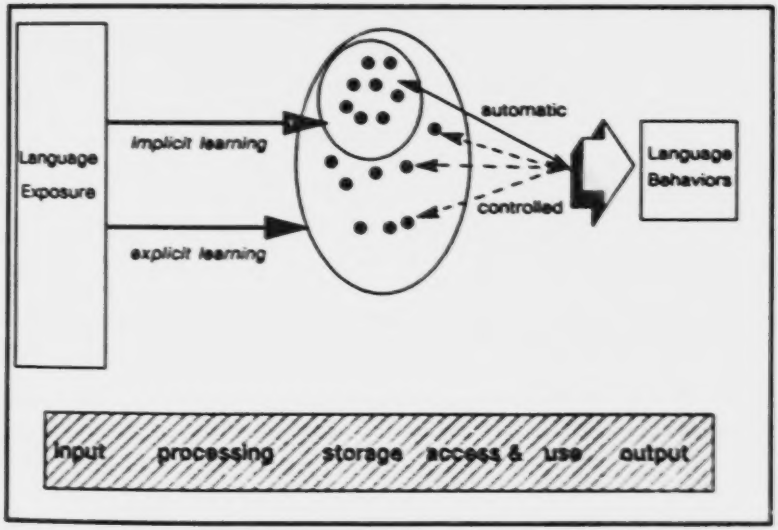

Figure 4. An Information-Processing Model

In place of two forms of knowledge storage in memory (Bialystok's explicit and implicit knowledge), McLaughlin's model hypothesizes one set of language data, which is stored within a system of nodes. These nodes are organized in storage according to the manner by which they entered the memory store *and* according to the processes through which they have been accessed by the learner. Information can enter the interlanguage

grammar either as analyzed (separate nodes) or as unanalyzed chunks of data (associated nodes). Grouped nodes are accessed, in their entirety, via automatic retrieval processes, whereas individual nodes must be pieced together slowly when accessed via conscious and controlled processes. But, according to McLaughlin, nodes that have entered storage independently through explicit (conscious) learning may eventually become associated (and, hence access to them may become "automatized") through drilling and rehearsal strategies by the learner (McLaughlin; Rossman, and McLeod, 38). Significantly, McLaughlin's conceptualization of information processing allows for the possibility that explicitly learned knowledge may become implicitly associated and, hence, that learning may lead to acquisition. While in agreement with Bialystok, McLaughlin's information-processing constructs provide an improvement over the "separate but related" notion of storage formats because they explain more about *how* bits of input may become associated during the access and use processing phase of second-language acquisition.

Two vital goals for CALL research are (1) gathering more data for the purpose of understanding the exact nature of the psycholinguistic processing involved in accessing and using a developing interlanguage system and (2) determining how such processing influences the organization of the system in memory. Learner logs that record in tandem the program stimuli (i.e., the screen displays or what the learner sees) and each learner response to it (i.e., what the learner types in or selects from the menu) give both researchers and teachers valuable insight into the strategies and processes students use while completing various language-learning tasks. Doughty and Fought (10) applied the learner log technique to investigate learner reliance on two complementary strategies of language data processing: *hypothesis testing* and *inferencing based on L1* (cognitive processes that may be seen as related to the implicit and explicit knowledge stores, respectively). In this investigation, learners were given complex verb-tense review material presented via an authentic-text format (in this case, a patient's hospital chart) accompanied by various kinds of "extra help" the students could consult by selecting from a screen menu. The kinds of extra help offered were designed to reflect the processing strategies learners might elect. For example, learners employing hypothesis-testing strategies might want to see other contexts containing examples of the verb tense in question, while learners using an inferencing approach might rely heavily on formal rules or examination of the correct answer. Results of the study indicated that students employed various strategies. Two general tendencies seemed to be determined by immediate outcome of the first attempt at a question. If learners were successful on the first try, the overwhelming majority went on to the next question without consulting any of the menu options. After a failed first attempt, learners usually availed themselves of the option to try again. It was when learners were wrong on second, third, or fourth tries that the results of the

study revealed a variety of learner strategies in the processing of the linguistic data available via the extra-help selections. Moreover, most learners demonstrated a preference for one type of extra help, indicating a consistent preference for one particular type of strategy.

The same design without computer learner logs would have obscured the important result that learner strategies are constrained by the immediate consequences of their first attempt but that individual preferences for processing strategy prevail under duress (i.e., after repeated wrong answers). However, more information is needed if the effect of the various strategies on interlanguage knowledge representation is to be understood. To this end, an additional benefit of using learner logs is the ability to track how students access and use their interlanguage system by documenting learner responses to computer tasks. For example, Doughty and Fought (10) suggest that consultation with extra-help options parallels Bialystok's notion of controlled access of explicitly learned knowledge and that attempts to complete tasks without any help from the program reflect automatic access to implicit knowledge in memory. An interesting followup study might seek to demonstrate that computer-based practice and drilling of explicitly learned knowledge can lead to the formation of implicitly associated node groups in memory storage that could then be accessed more automatically, as is suggested by McLaughlin (37). The computer's ability to time student responses might also be exploited in order to clarify the distinction between controlled and automatic responses so that the relative effects of different accessing strategies on storage can be determined.

Another investigation into the access and use of the developing interlanguage grammar (Boatman et al., 5) utilized the computer to administer a test designed to examine learner strategies in selecting verb tenses in French as a second language. This CALL study was a partial replication of a non-computer-based experiment (Fayol, 13) with better control over the testing environment provided by the use of the computer as a research tool. The purpose of the original study was to determine what influences native speakers in the process of selecting verb tenses for use in sentences. Extending the work to an investigation of second-language learning, Boatman et al. hypothesized that L2 adult learners of French would exhibit strategies for the selection of verb tense similar to adult native speakers of French rather than like those of children learning French as a first language. The original research showed that native adults rely on context, as determined particularly by the semantic content of adverbs in tense selection, and that children rely on verbal category (in French, verbs can be ranged along a continuum from stative to dynamic aspect). Results of the computer-based L2 study indicated, however, that for most verb tenses adult second-language learners are influenced more by verbal category than by the semantic environment. This study provides a first window into the cognitive organization data within the knowledge

representation store in memory and hints at a link between the processing strategies associated with the native language and the developing interlanguage. Furthermore, the detailed results provide data for formulating hypotheses about the exact nature and makeup of controlled and automatic access to language knowledge in memory. It could be that children learning a first language and adults learning their second language rely on explicitly organized knowledge, such as verb classification, to process linguistic phenomena, whereas native adults can intuitively and automatically appeal to the implicit information available in the association between the adverbial context and the verb.

Computerized Models of Information Processing

While the focus of this chapter is primarily on basic research into classroom language learning via CALL, computational abilities of the computer together with parsing algorithms for information processing have also been directed toward developing computerized models of the second-language learner. One such project, the development of a computer model of language production in an adult Japanese learner of English, has resulted in a computer program called CHIE (Gasser, 17). The CHIE project aims to characterize second-language production by examining computer processes that generate responses equivalent to the natural responses of learners on the same task. CHIE's particular emphasis is on the characterization of the causes of learner errors. CHIE may lead to a more detailed understanding of the processes involved in the comprehension of utterances as well as in the production of the target language. CHIE consists of a phrasal lexicon and a network of semantic associations. The phrasal lexicon provides the syntactic and morphological language data and the semantic network simulates the world knowledge needed to interpret and produce syntactic relationships.

CHIE works by first selecting grammatically defined patterns and then combining them according to constraints prescribed by the semantic network to produce surface utterances relevant to the goals that guide plans for language production. The program models several different language strategies that learners employ in the pursuit of a communicative goal but does so in the face of gaps in linguistic knowledge (similar to hypothesized gaps in developing interlanguage systems) that cause errors. (One example of a gap in linguistic knowledge is a phrasal lexicon entry that is not exhaustive enough to enable the program to decide whether a noun is countable or not.) Gasser argues that "characterization of the mental representation of linguistic knowledge and of the cognitive processes involved in language production is crucial to a theory of second language acquisition" (p. 23). Using the technique of incorporating into the program empirical data about actual errors made by second-language

learners, Gasser has shown, through computer modeling, that learners err primarily when they must deal with a communicative goal rather than in other circumstances.

Gasser also interprets his results in terms of McLaughlin's notion of processing constraints in order to demonstrate that production is as important to acquisition as is comprehension (as has been noted by both Bialystok and McLaughlin). Suggesting that the association may initially be weak immediately after a particular form has been associated with a function or meaning during comprehension. Gasser hypothesizes that for a given newly associated form to be accessed for production, there is a requirement that few other processing constraints be placed on the speaker. (In other words, the learner must focus on accessing this one form and is thus not capable of simultaneous access of others). Additionally, however, Gasser states that the process of accessing a form has the effect of strengthening the form–function association, thereby making the form more easily accessible at a future time, even under heavier processing constraints. The purpose of CHIE as a model of a second-language learner, thus, is to "explicate the nature of 'processing demands' and reveal under what circumstances the learner can use and strengthen new form–function relationships" (p. 2). The CHIE project has only begun to lay the groundwork for developing a full-scale computer model of second-language production. Current plans are to extend CHIE to a wider range of learner strategies, a system of hierarchical selection strategies, and a characterization of specific points in the process.

The Intake Model

While McLaughlin's proposal that language data is stored in memory in only one format helps to clarify the knowledge representation problem, much is left unsaid about the specific nature of the processes by which input enters the interlanguage system (the acquisition problem). Chaudron (6) suggests, however, that now "the issue for second language research is *precisely* what it is about the learner's language acquisition mechanism that determines intake, [i.e.,] the learner's perception and processing of target language input" (pp. 1–2). Acknowledging the existence of both the knowledge representation problem and the acquisition problem, Chaudron also discusses two independent aspects of second-language learning: (1) the learner's current state of knowledge of the target language (i.e., the internalized interlanguage); and (2) the processes and psychological variables that make up a learner's cognitive apparatus (i.e., the mechanisms for perception and learning).

Chaudron addresses both of these important issues, but seeks to examine in greater detail the psycholinguistic processing by which input becomes internalized. To this end, Chaudron has postulated that the same

set of cognitive mechanisms for SLA are at work as in first-language acquisition (Massaro, 36), but suggests that each learner's acquisition process is affected by a different set of interlanguage grammar rules. Moreover, Chaudron has further attempted to factor the internalization of input into several processing stages, proposing that each can be investigated separately to obtain the desired level of detailed analysis (see Figure 5).

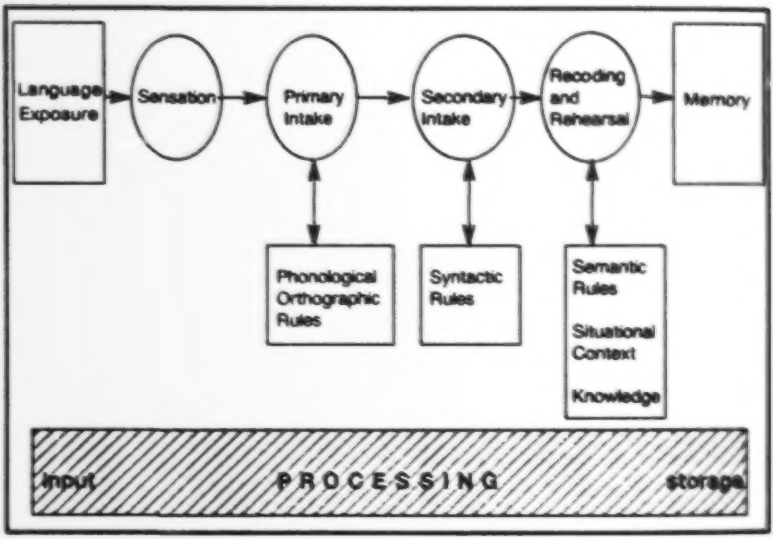

Figure 5. The Intake Model

According to Chaudron's Intake Model, a speech signal is first processed within the primary intake stage. Using phonological and orthographic rules from the existing interlanguage knowledge representation, neural impulses are analyzed partially and stored within short-term memory, which then sends out a filtered signal. Syntactic information is recalled during the temporary storage in memory, thus beginning a secondary stage in the intake processing. Finally, abstract representations of the language data are recoded according to semantic, situation, and world-knowledge information, and the fully decoded information enters the long-term memory store through recoding and rehearsal.

Whether these intake-processing stages are sequential is an important question that remains to be determined. Based on empirical research,

Garrod (16) has argued that the components of the internalization of input are simultaneous rather than sequential and has reported on initial empirical support for this assertion. In Garrod's study, when experimental subjects were interrupted during the processing of sentences, their responses indicated that, from the outset, they had assigned situational and semantic constraints to the interpretation of phonological, morphological, and syntactic information. Chaudron, on the other hand, calls for research to support a detailed model of stage-by-stage psycholinguistic processing and suggests that procedures from first-language acquisition research might be adapted for use in second-language acquisition studies. Chaudron's guidelines for research include the introduction of more control, directions for more standardized measures, and the implementation of a systematic approach to the analysis of each processing stage. Although CALL research has not yet addressed the detailed examination of information processing, Chaudron's suggestions for improving research methodology can be realized by exploiting various applications of the computer as a research tool for this purpose.

Interaction Theory

An alternative but potentially complementary approach to the psycholinguistic investigation of the processes by which input is internalized is offered by an interactional, or conversational, approach to the study of second-language acquisition. Rather than seeking to understand the nature of the psycholinguistic processing, Interaction Theory investigates language production that reflects the underlying internalization process (e.g., as exhibited in conversations). Several researchers who emphasize the importance of comprehensible input to second-language acquisition (Hatch, 20; Long, 26, 27, 28; Doughty and Pica, 11) have speculated on the role of interaction in making input comprehensible. Long, in particular, has claimed that modifications in the interactional structure of conversations between native and nonnative speakers, triggered by the native speaker's reaction to (or anticipation of) a lack of comprehension by nonnative, are what allow nonnative speakers to understand unfamiliar linguistic items they could not otherwise handle (in Krashen's terms, making $i + 1$ input comprehensible). Examples of the kinds of data examined in research motivated by Interaction Theory are modifications to the structure of interaction (seen below in Figure 6—Pica, Doughty, and Young, 43, pp. 5–6) such as (1) confirmation checks, (2) comprehension checks, and (3) clarification requests, as well as (4) repetitions or paraphrases of a previous speaker's or one's own utterances.

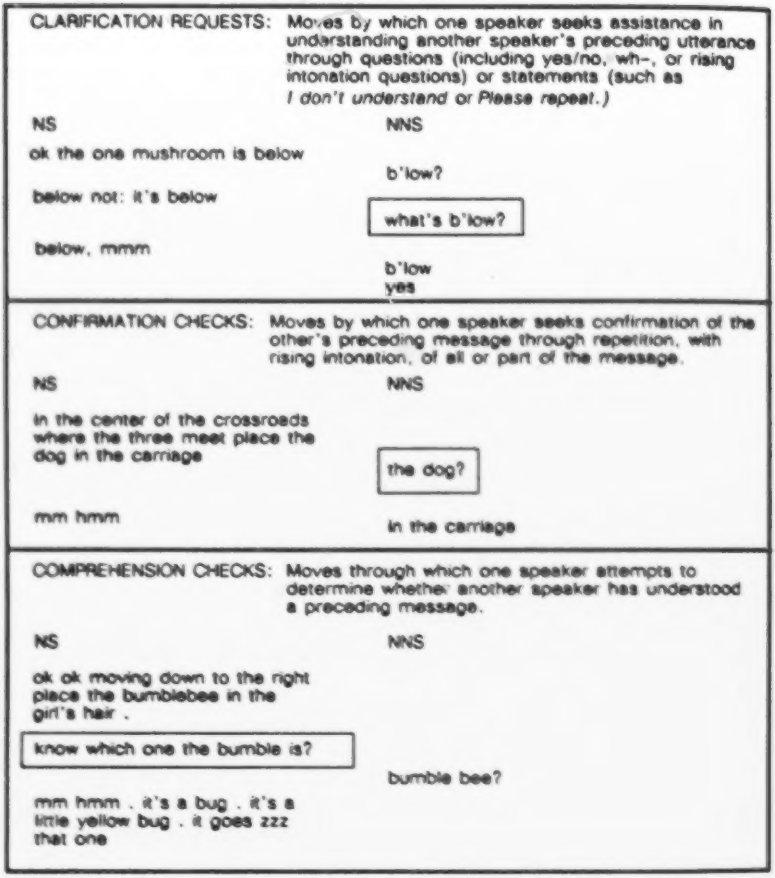
CLARIFICATION REQUESTS: Moves by which one speaker seeks assistance in understanding another speaker's preceding utterance through questions (including yes/no, wh-, or rising intonation questions) or statements (such as I don't understand or Please repeat.)
NS
NNS
ok the one mushroom is below
b'low?
below not: it's below
what's b'low?
below, mmm
b'low
yes
CONFIRMATION CHECKS: Moves by which one speaker seeks confirmation of the other's preceding message through repetition, with rising intonation, of all or part of the message.
NS
NNS
in the center of the crossroads where the three meet place the dog in the carriage
the dog?
mm hmm
in the carriage
COMPREHENSION CHECKS: Moves through which one speaker attempts to determine whether another speaker has understood a preceding message.
NS
NNS
ok ok moving down to the right place the bumblebee in the girl's hair .
know which one the bumble is?
bumble bee?
mm hmm . it's a bug . it's a little yellow bug . it goes zzz that one

Figure 6. Modifications to the Structure of Interaction

Although these kinds of modifications can be observed when native speakers converse with one another, they have been found to be statistically more numerous when native speakers engage in conversation with nonnatives. Hatch also suggests that the acquisition of syntax is a process parallel to the construction of discourse, and that the teacher acquires the function of different syntactic constituents by observing and utilizing them in conversation. Arguing that the most useful form of conversational interaction for SLA has participants talking creatively about topics that are not planned in advance, Hatch has described this interaction as conversation in which the outcome is negotiated by the participants. This is in

contrast to interaction for which the outcome is predetermined (e.g., display questioning in classrooms whereby, for the purpose of providing target language practice, teachers ask questions whose answers they themselves know and suspect that the students know as well). Figure 7 gives an overall indication of the role of interaction in the comprehension of input.

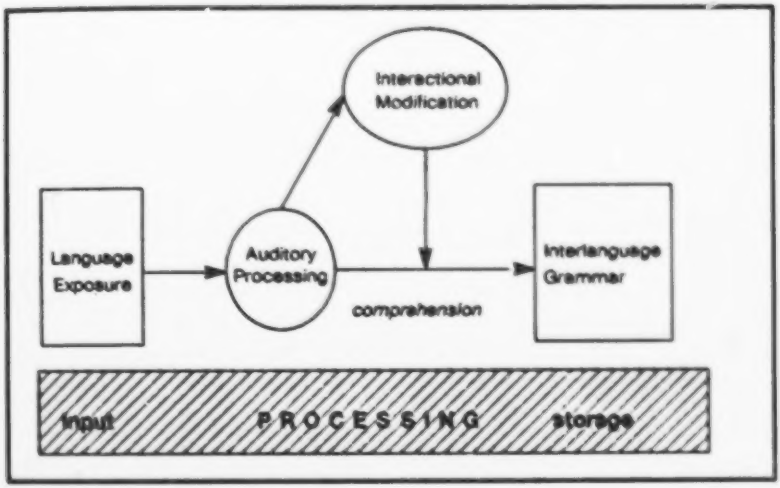

Figure 7. The Interaction Model

As with Information Processing, Interaction Theory also concerns itself with the input internalization phase of the overall language-learning process.

Coupled with an experimental design based on Interaction Theory (and notions from Monitor Theory as well) Doughty (9) has incorporated into a computer-based study at the University of Pennsylvania the CALL research methodology that relies on tracking learner responses in order to determine the effect of instruction on acquisition. In this study, instruction is defined as the presentation of structural material (relative clauses) within a specific framework that varies according to the experimental treatments applied. Rather than asking whether computer instruction is better than other forms of instruction, the primary aim of this study is to add empirical evidence in support of the beneficial effects of instruction on acquisition (see Long, 31, for a review). Whereas early studies investigating the role of the computer in instruction erroneously sought to establish the computer as a superior teaching tool, for Doughty the computer provides the medium for data collection and analysis.

Doughty relies upon SLA theory for determining the nature of the "extra help" material by using a program that provides branching via menu selection, thus enabling learners to select carefully controlled aids to the processing of language data. Learners are presented with the following reading activities while engaged in a computer L2 reading lesson: skimming, scanning (the treatment phase of the experiment), and recall. In the skimming phase, learners are instructed to glean the overall meaning of a passage and are guided by a highlighting of the topic sentences of each paragraph and a timing option that only allows a brief period of skimming time per page. During the scanning phase, one of three experimental treatments is presented: (1) presentation of the passage with extra reading time but no extra help provided (unstructured, unaided, but continuous processing), (2) presentation of the passage in chunks with formal rules available through the menu for the analysis of each chunk (a treatment parallel to traditional form-based approaches to instruction provided by calling up another program called Animated Grammar—Soemarmo and Graney, 51); and (3) presentation of the passage in chunks with information about the meaning of each chunk available by learner request through interaction with the menu (*please repeat; please say that again another way; please give the meaning of* [a specific word]). In this third condition, learners must obtain keys to the meaning of the passage chunks in much the same way as partners in a conversation interact to understand each other by clarifying, confirming, or checking comprehension (Doughty and Pica, 11). Doughty has hypothesized that the experimental condition based on Interaction Theory (condition 3 above), will lead to the greatest amount of comprehension as documented by reading recall tasks administered at the end of the session. Learners are to be pretested and posttested in an attempt to measure the effects of the three instructional treatments on acquisition. Because of its beneficial effects on comprehension, Doughty has hypothesized that the treatment that derives from Interaction Theory will have a greater effect on acquisition than will the extended processing format for the structure-oriented treatment.

Two recently completed studies that have also examined the learning process from an interactional perspective are those of Young (58) and Piper (45). Both researchers have noted the potential benefits of a frequent "spinoff" from text-based CALL activities: conversational interaction in the target language is often stimulated when learners work in groups or computer tasks. Both researchers tape-recorded and described the conversations of second-language learners as they cooperated in the completion of CALL program tasks; both assessed this interaction with regard to its potential influence on language learning as suggested by Hatch (20) and Long (30); and both aimed to examine whether the nature of the CALL software would determine differences in the kinds of conversation that occurred among learners engaged in these CALL activities.

Young's study, for example, was conducted within an Interaction Theory framework and asked specifically whether CALL activities that allow a negotiated outcome (primarily language-learning-oriented adventure games or simulations) vs. those for which the outcome is predetermined (i.e., word sequencing and cloze testing programs) would generate different kinds of conversational interaction among learners. Young reported that the task determined the kind of conversation generated; programs that allowed for the negotiation of outcome produced more creative language than tasks for which the outcome is predetermined by the program itself. Young interpreted the results of this study from the perspective of an interactional model of language learning and observed that open-ended activities that allow for creative learner conversations (1) are promising for CALL software development and (2) indicate an important direction for empirical research.

Piper (45) similarly examined CALL conversations according to a number of categories of conversation types, including several of Sinclair and Coulthard's (50) well-known observational categories, and noted that three kinds of language are typical of the conversations among students who are working in groups on computer tasks: (1) *repeating* language from the screen, (2) *managing* the computer and the task, and (3) *discussing* the language task itself while working towards a solution or the completion of the task. Not surprisingly, the type of CALL program used was found to determine the nature of the exchange. Cloze tasks primarily produced management language, word-ordering tasks resulted in a large amount of repetition, and none of these tasks caused much discussion. While the results of both Young's and Piper's studies provide a good deal of descriptive, empirical data about the nature of learner conversations generated during CALL activities, Piper suggests some reasons for restraining the enthusiasm for the direct-application interactional CALL in the classroom, pending more investigation. Upon detailed examination "CALL tasks . . . appear to give rise to two types of discourse—an apparently incoherent one where learners are thinking aloud and a more coherent one where they are exchanging information" (p. 194). Furthermore, "CALL tasks appear to provide no opportunity for language learners to develop the more demanding ability to construct 'long turns'" (p. 194). And, moreover, when the range of language and variety of language functions generated by CALL activities are analyzed, "the discourse [is] impoverished" (p. 196). Obviously, more investigation like that of Young and Piper is needed in order to determine whether the inter-learner conversations around CALL tasks are representative of those that have been theorized to be beneficial to the development of syntax in second-language acquisition, according to the interactional framework. Furthermore, efforts toward developing CALL materials that foster such useful interaction must be initiated.

Connections between Research and Classroom Teaching

Much research into classroom language learning has reflected a "person-oriented approach that examines characteristics of the supposed good language learner: intelligence, personality, cognitive style, motivation and attitude" (Nation and McLaughlin, 40, p. 41). However, the problems of "person" or learner-oriented research are numerous: (1) valid measures of learner variables not subject to interaction with other variables are difficult to obtain, (2) the collection of data uncontaminated by factors outside of the design of the study is virtually impossible, and (3) the generation of empirical evidence of these kinds of factors is cumbersome at best.

Building the computer into a research design for the investigation of learner characteristics offers these advantages: (1) better control over other cognitive variables, (2) the capability to isolate a particular learner variable, (3) the control necessary for understanding the interaction between learning conditions and the learning process, and (4) a more direct and connected way to evaluate learning outcomes. All these advantages combine to provide a firmer foundation for making inferences about and gaining insight into the central learning process. One example of a computer-based approach to research is the investigation of the role of the cognitive variable "field-dependence" (involving the relationship between the ability to differentiate the small parts from complex wholes) in language learning. Several non-computer-based studies (Naiman et al., 39; Hamayan et al., 19) have supported the hypotheses that the field-independent individual (who can see the smaller parts) is a better language learner. These studies failed, however, to control for other equally essential cognitive variables such as IQ and aptitude, known to be highly interactive (Stern and Cummins, 55), and gave no consideration to the possible interaction between learning conditions and learner characteristics. As such, the field-dependence variable under consideration could not be isolated and any conclusions drawn about learning outcomes were too general to be supported by the data.

Mellgren (41) conducted a computer-based study that attempted to measure the combined effects of relative field dependence (other cognitive factors were controlled for) and a clearly defined instructional context, computer homework. Mellgren used the computer as a medium for out-of-class practice and thus greater control was maintained over the learning conditions. Learner characteristics were identified and partialled out by means of rigorous pretesting so that only the cognitive variable under investigation was considered in the final analysis. Results indicated that the cognitive trait of field independence could consistently predict success on computer homework, whereas students who were field dependent could be counted on not to do as well. While not an investigation of the learning process, as with the majority of the studies reviewed

above, Mellgren's study presents important implications for the appropriate use of the computer in foreign language instruction with respect to the combined effects of learning characteristics and learning conditions. Mellgren's work also demonstrates that the amount of *control* offered by computer-mediated research is one possible solution in the effort to conduct "cleaner" studies. For example, using the computer as a research medium, time of exposure to the language data as well as the nature of the linguistic material itself can be strictly controlled, environmental factors can be standardized, and learner responses can be monitored and, more importantly, recorded in detail.

In the majority of the studies mentioned above, the computer is either an instrument that collects data or is medium of instruction. Both roles are useful in classroom-oriented research because information is generated about what learners actually do in lessons. Interestingly, this often turns out to be different from what they think they are doing, and also from what they have been trained to do. Garrett (15) has called this "getting at what is going on inside students' heads" while they are learning a foreign language. Using a methodology that combines classroom observation, teacher "hunches," and the computer as a data-collection instrument, Garrett (Chapter 7 in this volume) proposes a system of conducting ongoing classroom research that feeds directly and immediately back into classroom teaching and learning. Specifically, Garrett suggests that the computer makes classroom observation convenient and precise through the simultaneous collection of data from several individual students. The computer feeds directly into teaching hypotheses generated from global classroom observations that can then be tested directly via the computer medium with the very students on whom the original observations were made. Production data (learner output) is the kind most frequently gathered on the computer, but with the audio components now readily available to computer instruction, listening comprehension data may also be collected in a similar fashion. Garrett suggests that classroom research is important because the questions that teachers feel are worth following up in the classroom can be the first questions to be investigated. In this way, the benefits of CALL research are threefold: (1) there is immediate feedback to teaching, (2) benefits accrue in the classroom, and, (3) there is an overall benefit to the field of applied linguistics. Garrett further notes that it is important to find out what learners actually learn—as opposed to what they are taught—and why and to what extent learning is affected by teaching. Once there is some sense of what idiosyncrasies students hypothesize about language, then, for one applied example, the true individualization of foreign language instruction can come into place.

The dissertation work of Garrett (14) applied the system of cyclical observation and hypothesis generation to the investigation of the development of complex grammatical structure in German as a second language (GSL). Garrett's study sought to provide empirical support, from the

classroom, for the Interlanguage Hypothesis, which, as originally put forth by Corder (7) and Selinker (49), asserts that the development of complex structure in L2 proceeds through a series of grammars that approximate its grammar. The Interlanguage Hypothesis stresses, however, that each approximative grammar is a system on its own and, therefore, the interlanguage grammar should not be seen merely as an imperfect reflection of the target language grammar. In terms of learner output, the Interlanguage Hypothesis emphasizes the importance of viewing learner errors as windows into the systematic development of the interlanguage grammar rather than as "mistakes" in the target language. Of specific interest to Garrett was the systematic relationship between the dative case and indirect objects in the development of GSL interlanguage grammars and a relevant hypothesis based on a classroom observation about how students learn (or fail to learn) the details of the relationship. Garrett reasoned that students typically did not add dative case endings to indirect objects because they did not understand what a direct object was rather than because they did not understand the dative case. All students were pretested to see if they knew the dative paradigm and only those students who did were included in the study, which focused on this grammar point in drill-and-practice exercises. Student production data collected on dative case vs. accusative case on indirect vs. direct objects revealed a number of interesting observations about the interlanguage grammars of GSL students:

1). Students distinguished between dative and accusative on the basis of whether the objects were animate or inanimate, a "rule" that generates the right answer 90 percent of the time but is not the actual rule.

2). Students only have trouble with dative case when the dative is required of a pronoun, a paradigm that is considered to be the hardest to learn in German.

3). Students get case endings right when both objects are nouns, but when the indirect object is a clause, it is always marked in the accusative; this again is a rule that almost always produces the right answer but is not the native one.

Garrett also discovered interesting strategies adopted by students when they got a wrong-answer markup from the computer program and were asked to do an immediate second try:

4). Some students routinely changed the ending to a different case. From this strategy, Garrett gleaned that they had no idea of what "case" really does in a language; in other words, they know case exists, they know how to form the endings, but they do not know its function.

5). Other students left the ending unchanged in favor of changing the root of the word; when asked why, students said that they assumed they had gotten the stem wrong.

From these two kinds of data, Garrett has concluded that the ability to correct grammar mistakes is not always an indication that the original error was some kind of performance error (as has often been suggested). In light of the relevance of Garrett's data to the Interlanguage Hypothesis, this result is a very important notion that merits further investigation.

Conclusion

This review of the connections between SLA theory and CALL research has emphasized the necessity for re-establishing the link between theory, research, and classroom methodology. Cooperative research efforts are necessary if the complex process of second-language acquisition is to be understood and if any of the progress in theory building is ever to be useful to classroom language teachers. Moreover, in this chapter, classroom-oriented research (particularly involving hypotheses generated from classroom data together with the recycling of the research results back into the classroom) has been suggested as a very promising source of empirical knowledge about the language learning process. Equally important, the chapter has underscored the role of the computer as an indispensible research tool and revealed its potential in contemporary CALL research. Still, however, there is a need for an integrated effort toward understanding second-language acquisition, starting with theoretical frameworks that are motivated by the concerns of teachers and researchers and resulting in large amounts of data collected under classroom conditions.

At present there are some research efforts that seek to establish and develop such a unified approach. One group currently forming proposes to design an intelligent tutorial called the Plus One System (Yao and Ross, 57). The researchers hope to enhance the design of Plus One by considering both the SLA literature and the experiences (and intuitions) of language teachers and learners. Plus One will be developed in stages in order to accommodate any progress made by SLA theoreticians in addition to any advances in the technology of computers and will have capabilities for incorporating a number of teaching methodologies. Although named for Krashen's Input Hypothesis, the designers of Plus One have noted some of the difficulties with Monitor Theory and, thus, have adopted a modular and flexible approach that is not strictly tied to any one theoretical model. Plus One also will maintain a database for the purpose of modeling each student's current interlanguage. Such information will be useful both for the collection of empirical data and for including a computer-diagnositic component in the system. Yao and Ross have identified the need for a cooperative effort by teachers, researchers, and CALL designers; accordingly, they have set a time framework of five to ten years for completing the Plus One intelligent tutoring system for TESOL.

Another long-term project is the establishment of a cooperative research effort among leading researchers in applied linguistics at the National Foreign Language Resource Center (R. Lambert, Director). The center, to be located at Johns Hopkins University, will be staffed by researchers and teachers from universities across the nation. The goal of cooperative research at the National Foreign Language Resource Center is to investigate a number of important and related issues in second-language acquisition and language teaching. Some of the important research areas are to be classroom research, the measurement of proficiency, comparisons of methodology, individual learning differences, and the special considerations of very complex and uncommonly taught languages such as Japanese and Chinese. The computer as a research and data-sharing tool is a central link in this cooperative effort. Using a network of computers, data will be circulated among researchers, analytical tools will be developed, and databases will be created.

Efforts such as the cooperative work on the Plus One system and the establishment of the National Foreign Language Resource Center—which encourage the collaboration of researchers and teachers in developing a theory specifically oriented toward SLA—in time may bring the field of applied linguistics closer to understanding all elements of Spolsky's (53) question: "Who learns how much of what language under what conditions?" In the interim, the computer and CALL remain important instruments to help clarify the process of second-language acquisition, and, as such, promise to facilitate a new connection between pedagogy and SLA theory.

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